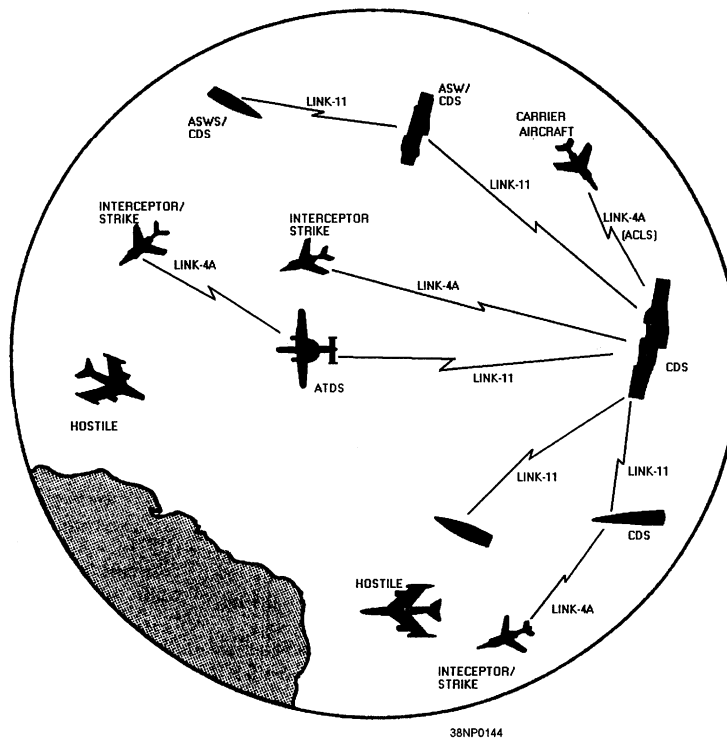


## CHAPTER 2

# THE LINK-11 SYSTEM

### INTRODUCTION

Tactical data links are usually limited to a specific area of operation and are used for command and control of specific forces. Link-11 is the U.S. Navy shipboard version of NATO's Tactical Data Information Link "A" (TADIL A). The Link-11 system is used to provide high-speed, computer-to-computer exchange of digital tactical information among ships, aircraft, and shore installations, as shown in figure 2-1.



**Figure 2-1.—Tactical digital information links.**

Link-11 data communications can operate with either high-frequency (HF) or ultra-high-frequency (UHF) radios. In the HF band, Link-11 provides gapless omnidirectional coverage of up to 300 nautical miles from the transmitting site. In the UHF band, the Link-11 system is capable of line-of-sight omnidirectional coverage, approximately 25 nautical miles between ships and 150 nautical miles for ship-to-air links.

To understand the operation of the Link-11 system fully, you must be able to identify the hardware components that compose it and the functions they perform. Keep in mind that although the specific equipment used on board your ship may differ from the examples used in this chapter, the purpose of your Link-11 setup is still the same, that is, to pass tactical data to other units.

After completing this chapter you should be able to:

- Describe the composition of a typical Link-11 system.
- Describe the operation of the Link-11 transmission and receive cycles.
- Describe the six operating modes of the Link-11 system.
- Describe the function of the Link-11 encryption (security) device.
- Describe the audio tones generated by the Link-11 Data Terminal Set.
- Describe the word formats used to transmit Link-11 tactical data.
- Describe the message formats used in the various Link-11 operating modes.
- Describe the operation of the Link-11 Data Terminal Set.

## LINK-11 FUNDAMENTALS

To monitor the operation of and perform maintenance on the Link-11 system, you must understand how the different pieces of equipment interact with each other. Let's take a look at a basic Link-11 system.

### LINK-11 SYSTEM OVERVIEW

A typical shipboard Link-11 communications system (figure 2-2) consists of the following components: the CDS digital computer, a cryptographic device, the Link-11 data terminal set, the communications switchboard, and the HF or UHF

radio set transceivers (transmitter/receiver), an antenna coupler, and an antenna. The data terminal set is the center of the Link-11 system and is covered in detail later in this chapter. The communications switchboard is used to select the desired HF or UHF transceiver. An external frequency standard is also part of many Link-11 systems. Additionally, the **Shipboard Gridlock System** (SGS) is installed on many ships. On SGS-equipped ships, an AN/UYK-20 is placed in the line between the CDS computer and the crypto device.

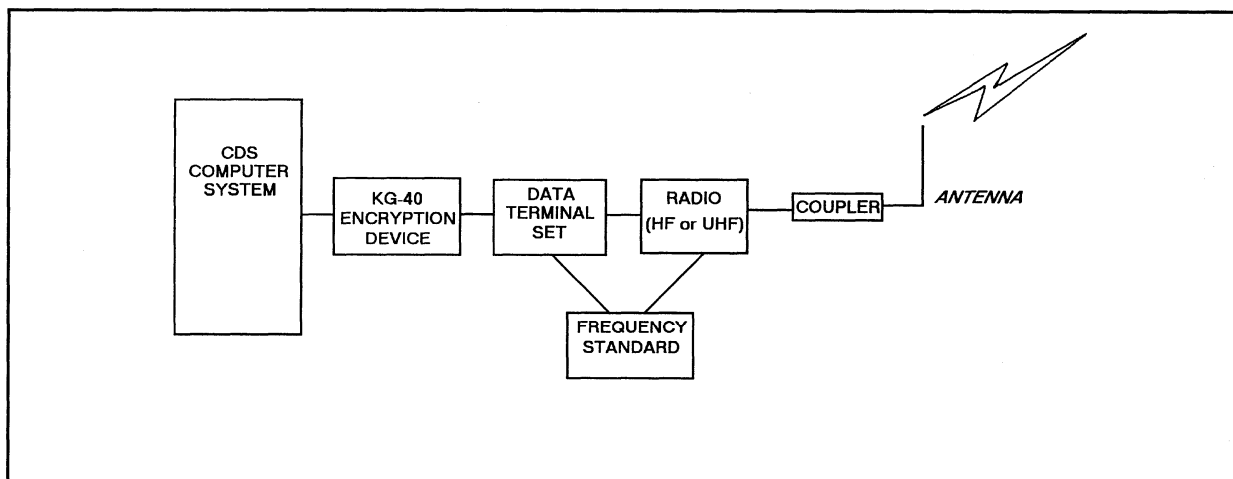


Figure 2-2.—The Link-11 communications system.

## CDS Computer

The central processor of the Combat Direction System is the CDS computer. Keeping a data base of tracks is among the many functions of the operational program. The information about these tracks can be transmitted to other units over the Link-11 net. The computer sends data to the data terminal set using 24-bit data words. The computer also receives information about remote tracks from other units in the net and displays these tracks through the display system.

## Shipboard Gridlock System

**Gridlock** is the matching of track positions held by other ships with the tracks held by your own ship. Gridlock is a procedure for determining data registration correction by comparing remote tracks received from a designated reference unit to local data. Ideally, tracks received from remote units that are also displayed by onboard sensors should be transparent, that is, in the exact same position on the CRT. If the gridlock system does not provide correlation between local and remote tracks, the remote tracks may be painted twice and overlap each other, as shown in figure 2-3.

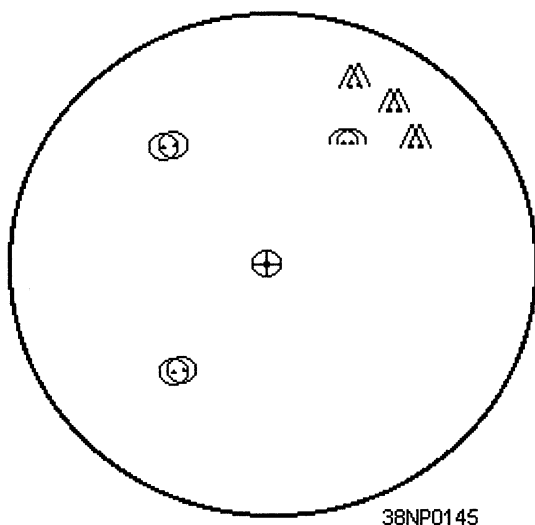


Figure 2-3.—Tracks out of gridlock.

Failure to maintain gridlock maybe the result of inaccurate positioning data from a ship's sensor, from the Ship's Inertial Navigation Systems (SINS), or

from the ship's gyro. Failure to maintain gridlock may also be the result of an inaccurate operator entry.

The SGS computer performs continuous automatic gridlock calculations. In the event of an SGS computer failure, the flow of Link-11 data to the CDS computer is interrupted. To restore Link-11 data flow, all SGS installations have switches installed that allow the technician to bypass the SGS computer until the fault is corrected.

## Link-11 Security Device

A standard model security device, such as the TSEC/KG-40, commonly referred to as the KG-40, is used with the Link-11 system. When the DTS is transmitting data, the KG-40 receives parallel data from the CDS computer, encrypts the data, and sends it to the DTS. When the participating unit (PU) is receiving data, the TSEC/KG-40 receives encrypted data from the DTS, decrypts, and sends to the CDS computer.

Because of the specialized training and security requirements of cryptographic equipment, we will not cover the internal operation and controls of the security device.

## Data Terminal Set (DTS)

The data terminal set (DTS) is the heart of the Link-11 system. The DTS is the system modulator/demodulator (MODEM). The CDS computer sends 24 bits of data to the DTS via the SGS computer and the encryption device. The DTS adds six bits of data for error detection and correction. These six bits are called **hamming** bits. The 30 bits of data are phase shift modulated into 15 audio tones. These 15 data tones and a Doppler connection tone are combined into a composite audio signal which is sent to either the UHF or HF radio for transmission.

The DTS receives the composite audio signal from the radio and separates the 15 data tones and the Doppler correction tone. The 15 data tones are demodulated into 30 data bits. The six hamming bits are checked for errors and the 24 data bits are sent to

the CDS computer via the encryption device and the SGS computer.

## **Link-11 Communications Switchboard**

The communications switchboard provides system flexibility and casualty recovery capabilities by allowing manual switching of the data terminal set and individual HF and UHF radios. A typical switchboard will provide the following interconnections:

- The Link-11 data terminal set to one or more HF radio sets to provide the standard HF Link-11 capability
- A Link-11 data terminal set to one or more UHF radios sets to provide UHF Link-11 capability

The same communications switchboard may also be used for connecting a Link-4A data terminal set to one or more UHF radios to provide standard UHF Link-4A (TADIL C) capability. Link-4A is covered in detail later in this book.

## **Radios**

The Link-11 system can operate with either an HF radio or a UHF radio. Long-range communications are achieved by the use of the HF system. UHF communications are limited to line of sight. "Line of sight" means the radio wave will not bend over the horizon; therefore, the use of an antenna mounted high on the mast will increase the range of UHF communications.

## **Antenna Couplers**

Antenna couplers are used to connect a specific radio set to a specific antenna. The coupler provides for the correct impedance matching of the antenna and the radio set. For many of the multi-couplers to work properly, it is extremely important that the correct frequency spacing be observed. A general rule is to ensure a frequency spacing of 15 percent. Frequencies that are too close together can cause interference and distortion, increasing the signal to noise ratio and causing bit errors in the data.

## **Antennas**

In oversimplifying the theory of antenna operation, an antenna is just a piece of wire that radiates electromagnetic energy from the radio into the atmosphere and converts atmospheric electromagnetic radiation into RF current to be processed by the radio. As electromagnetic energy from the atmosphere passes through this wire, it induces a current in the wire. This current is fed to the radio receiver. If the receiver is tuned to the same frequency as the received signal, the signal can be processed. The same wire will radiate an electromagnetic field if current is flowing through it.

The frequency at which a radio operates determines what size antenna is most suitable for transmitting and receiving. The higher the frequency, the smaller the antenna will be. Lower frequencies require larger antennas. For example, the full-wave length of an antenna designed to operate at 4 MHz is about 250 feet. Since this is too long for shipboard application, antennas are designed in submultiple lengths. These include half-wave and quarter-wave antennas.

An antenna can be tuned by introducing a capacitive or inductive load. This loading effectively changes the electrical length of the antenna and can be used to extend the frequency range of the antenna. For more information on antenna design and operation, refer to the Navy Electricity and Electronics Training Series, Module 10, *Introduction To Wave Propagation, Transmission Lines, and Antennas*, NAVEDTRA B72-10-00-93.

## **Transmission Cycle**

The data flow for the Link-11 transmission cycle is shown in figure 2-4. The CDS computer receives data from the various ship's sensors, navigation systems, and operator entries, and stores this data in a data base. When a Link-11 transmission is required, the computer outputs parallel digital data through the SGS computer to the cryptographic device. The cryptographic device encrypts the data and sends the encrypted data to the data terminal set (DTS). The DTS converts the digital data to analog audio tones,

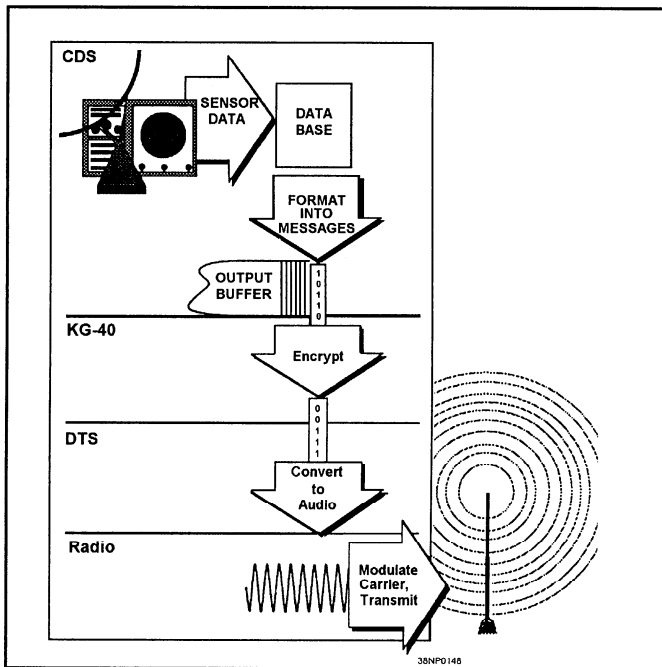


Figure 2-4.—Link-11 data flow for the transmit cycle.

keys the transmitter using the radio set keyline, and passes the audio tones, via the communications switchboard, to the transmitter for modulation to the RF carrier signal. The radio set keyline is a signal that switches the radio to the transmit mode. When the signal is stopped, the radio reverts to the receive mode.

When you are using the HF band, the radio frequency signal modulation uses amplitude modulation independent sideband; that is, the upper sideband (USB) and lower sideband (LSB) are transmitted independently in an effort to overcome propagation-caused signal losses. The UHF radio uses frequency modulation; therefore, only the USB is used.

## Receive Cycle

When a transmitted signal is received, the receiver demodulates the audio tones from the RF carrier and passes them via the communications switchboard to the DTS. The DTS demodulates and demultiplexes the audio tones into digital data. The digital data is sent to the cryptographic device where it is decrypted and sent to the CDS computer for processing.

## LINK-11 NET OPERATING MODES

Before we look into the actual operation of the data terminal set, you need to have some knowledge of the Link-11 modes of operation and how the messages are formed. Link-11 employs networked (net) communications techniques for exchanging digital information among airborne, land-based, and shipboard systems. As you have seen, the amount of hardware required to support Link-11 operations is relatively small; however, establishing and maintaining a successful link can be very complex.

### Establishing a Link-11 Net

The establishment of a successful link involves the interaction and teamwork of the operators and technicians of several units working towards the common goal. If one unit is having trouble with the link radio, data terminal set, or other equipment, it can make the entire link unreliable.

When a task force is about to deploy, the task force commander will issue a message that has the necessary information required to establish Link-11 communications. The information in this message includes a list of primary and secondary frequencies, designation of the initial net control station, an initial gridlock reference unit (GRU) designation, PU identification and addresses, an initial data link reference point (DLRP), and required operating procedures. Voice communications are required for net control and coordination during initialization.

When the task force is formed, the picket stations inform the net control station (NCS) of their readiness to establish link operations. Upon establishing communication with all units, NCS transmits Net Synchronization (Net Sync). If the NCS is using corrected timing (normal mode), the Net Sync verifies the communications path between NCS and all picket units. If a picket unit cannot receive Net Sync, it cannot participate in the net. Net Test should follow Net Sync. Net Test is used to confirm connectivity between the Link-11 units. Units having difficulty in receiving Net Sync or Net Test should report to NCS that they are not able to participate in the net and then begin corrective action.

When Net Test is completed, all picket stations report their status to NCS. Then NCS directs all PUS to switch to the Roll Call mode and initiate link operations. Net Synchronization and Net Test are used in the initialization of the net. The normal mode of operation is Roll Call.

The above scenario has introduced you to several new terms and modes of operation. These are explained in detail in the following paragraphs.

The following are the six modes of Link-11 operation:

- Net Synchronization
- Net Test
- Roll Call
- Broadcast
- Short Broadcast
- Radio Silence

### **Net Synchronization**

The Net Sync mode of operation is used to establish a uniform time base from which all net data communications normally initiate. The Net Sync mode is usually initiated when establishing a link net after all operator entries have been properly completed. The Net Sync transmission is manually started by the operator on the NCS platform and continuously transmits the Link-11 preamble until stopped by the operator.

The preamble consist of two tones—the 605-Hz tone and the 2,915-Hz tone. During the transmission of Net Sync, the 2,915-Hz tone is periodically phased shifted 180 degrees. The time between these shifts is determined by the selected data rate and is called a frame.

Each PU is equipped with a very accurate time base in the form of a frequency standard (internal or external). When the NCS transmits Net Sync, each

unit receiving the transmission synchronizes its individual time base with the Net Sync signal. If the picket station is operating in the corrected sync mode, as is normally the case, the picket will check to see that it can recognize the Net Sync signal as a means of verifying that a good radio link has been established. If a picket is going to operate in the stored sync mode, it will align its stored frame timing to the timing of the NCS, using the received Net Sync signal. Since stored sync timing locks the picket to the time base of the NCS, data from other pickets may be lost. Therefore, this mode should only be used during times of poor radio propagation or signal jamming. After the completion of Net Sync, the next operation performed in establishing a link is usually Net Test.

### **Net Test**

Net Test provides an overall evaluation of the net and equipment performance. When you are operating in this mode, NCS will broadcast canned test data to all pickets within the net. The data terminal set contains a code generator that generates twenty-one 30-bit data words. Once all the words in the word table have been generated, the process automatically starts over and keeps running until stopped by the operator.

Net Test will test the connectivity between all units and the operation of the DTS. Since it is a local test, Net Test does not check the interface between the CDS computer and the DTS. Net Test is also helpful to the technician for setting the audio input and output levels of the DTS or radio set.

### **Roll Call**

Roll Call is the normal mode of operation. In this mode, the operator on the NCS platform enters ownship's address and an assigned address (PU number) for each PU in the proper switch position. When the link is initiated, each PU is polled for data. Polling consists of sending a call-up message. If the PU fails to respond, the call-up is repeated. If the PU still does not respond, it is skipped and the next PU is polled. When a PU recognizes its own address, the PU will transmit its data to all the participants in the link. When the NCS recognizes the end of the PU

reply, it automatically switches to the transmit mode and calls up the next PU address. After all the units in the net have been polled, the NCS transmits its own data and the process is continuously repeated. The Roll Call mode provides all PUS with continuous, near real-time exchange of tactical information.

## Broadcast

When the Broadcast mode is used, one PU will continuously send a series of data transmissions to all the members of the net. Once manually initiated, the transmission will continue to be sent automatically until the operator manually stops it. Through the use of the broadcast mode, other picket stations can receive real-time tactical information without breaking radio silence.

## Short Broadcast

In the Short Broadcast mode, a picket station or the NCS sends a data transmission to the other members of the net. The transmission is initiated by the operator depressing the TRANSMIT START button on the DTS control panel and is terminated automatically when the computer has finished sending the DTS data. This mode is used only when no other unit is transmitting.

## Radio Silence

In the Radio Silence mode, the radio set key line and the data terminal set audio output are disabled. The receive capability of the DTS is not affected. The Radio Silence mode is manually initiated and terminated.

## BUILDING A LINK-11 MESSAGE

Information transmitted from the DTS originates from two sources. Tactical data always originates from the CDS computer. Other information, including the **preamble**, **phase reference**, **start** and **stop codes**, and **address frames**, originates within the data terminal set. These additional special-purpose frames are added to the data frames to form the proper messages.

For the DTS to control the net properly, strict adherence to the correct message format and net protocol are required. Every Link-11 message has a specific format and function. Each Link-11 message generated by the DTS begins with a header consisting of the **preamble** (five frames) and the **phase reference frame** (one frame). Control codes, such as the start code, the picket stop code, and the control stop code, are also required.

## Preamble

The preamble, as previously covered, consists of a two-tone signal. The two tones are the 605-Hz Doppler tone and the 2,915-Hz sync tone. The preamble is five frames long and is transmitted at four times the normal power, as shown in figure 2-5. A more detailed explanation of the preamble tone is provided later in this chapter.

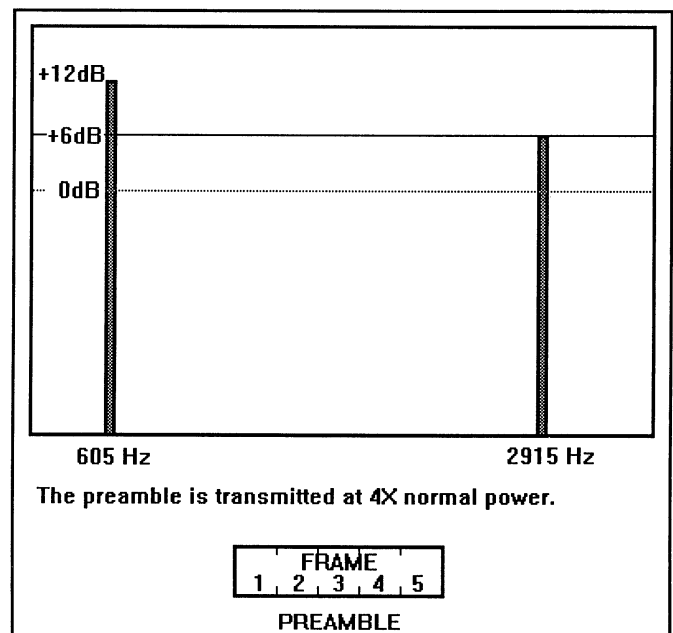


Figure 2-5.—The Link-11 preamble power levels and frame count.

## Phase Reference Frame

The phase reference frame follows the preamble and is shown in figure 2-6. This frame is composed of the normal 16-tone composite signal with the data tones transmitted at 0 dB and the Doppler tone transmitted at +6 dB. The phase reference frame

provides the reference for the first frame of data. Each succeeding frame becomes the phase reference for the following frame.

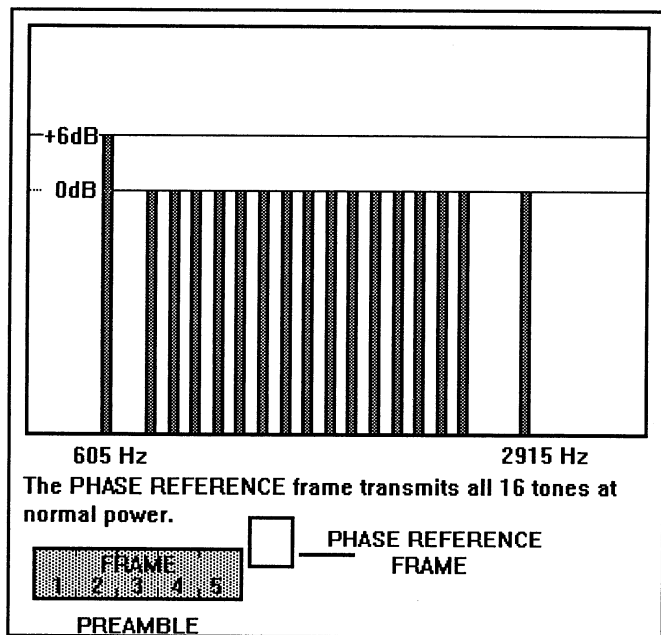


Figure 2-6.—The phase reference frame added to the preamble with normal data tone levels.

## Information Segment

The information segment of the Link-11 message is composed of control code frames and message data frames. Control code frames consist of a start code, a stop code, and an address code. Each control code is two frames in length and performs a specific function. Control codes are not sent to the CDS computer.

**START CODE.**— The start code is a two-frame code that follows the phase reference frame, as shown

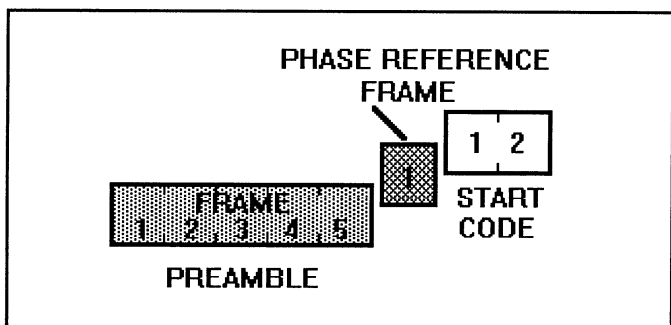


Figure 2-7.—The start code added to the Link-11 transmission.

in figure 2-7. When sensed by the DTS, the start code causes the DTS to send a **prepare-to-receive data interrupt** to the CDS computer.

**MESSAGE DATA FRAMES.**— Message data frames contain the tactical data being disseminated and follow the start code, as shown in figure 2-8. The number of message data frames depends on the amount of tactical information the unit transmits. The 24 bits of data contained in each frame is sent to the CDS computer.

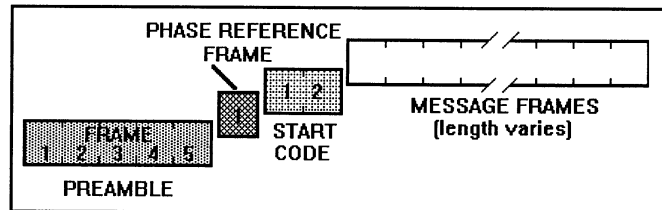


Figure 2-8.—The message data frames added to the Link-11 transmission.

**STOP CODE.**— The stop code is a two-frame code that follows the data message in a Link-11 transmission and is shown in figure 2-9. There are two types of stop codes: the **control stop code** and the **picket stop code**. The control stop code is used in messages originated by NCS (NCS report) and indicates that a picket address code follows the stop code. The picket stop code indicates to the NCS that the picket unit has completed its message transmission. Both the control stop code and picket stop code cause the receiving DTS to send the **End-of-Receive interrupt** to the CDS computer.

## LINK-11 MESSAGE FORMATS

The formats of the messages transmitted by the Link-11 system vary with the mode of operation.

### Roll Call Mode Messages

In the Roll Call mode, the unit designated as the net control station sends out two types of messages. These are the NCS call-up message (interrogation) and the NCS report (message with interrogation). A third message, the picket reply message, is sent by picket unit in response to interrogation messages.



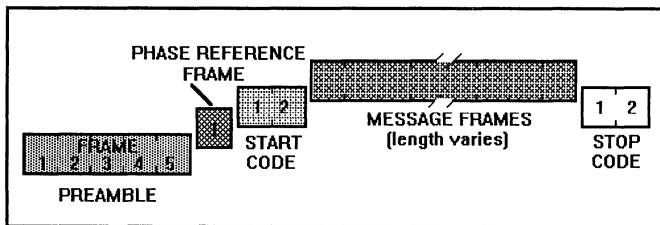


Figure 2-9.—The stop codes added to the Link-11 transmission.

### CALL-UP (INTERROGATION)

**MESSAGE.**— This message shown in figure 2-10 consists of the five-frame preamble, the phase reference frame, and the two address frames. The call-up message does not use start and stop codes.

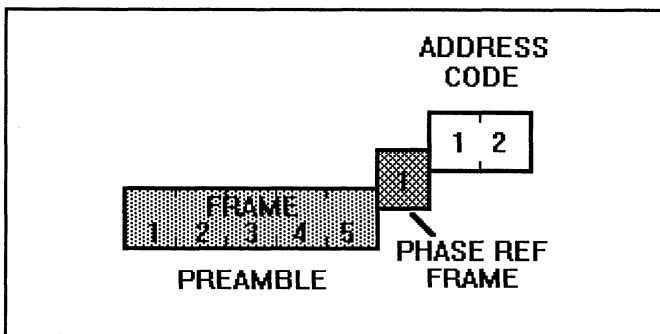


Figure 2-10.—The NCS call-up message.

### NCS REPORT AND CALL-UP

**MESSAGE.**— This message shown in figure 2-11 consists of the five-frame preamble, the phase reference frame, the two-frame start code, the data frames containing the NCS report, the two-frame control stop code, and two frames containing the address code for the next PU.

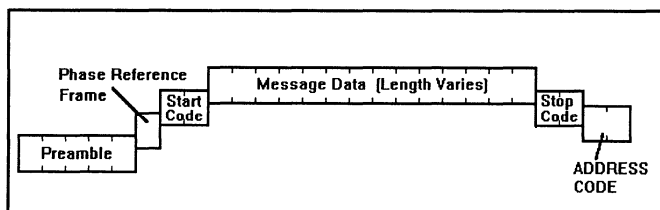


Figure 2-11.—The NCS report message.

**PICKET REPLY MESSAGE.**— The picket reply message shown in figure 2-12 consists of the five-frame preamble, the phase reference frame, the

two-frame start code, the data frames, and the two-frame **picket** stop code.

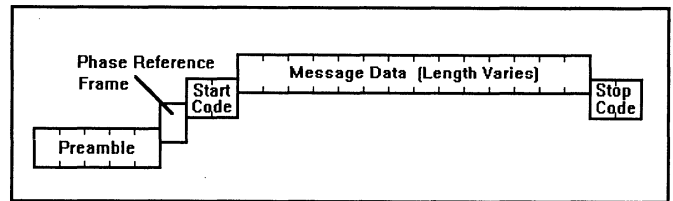


Figure 2-12.—The picket reply message.

### Short Broadcast Messages

The Short Broadcast is a single data transmission to all members of a net by a station that may be acting as either picket or NCS. It is the same format as the picket reply message shown in figure 2-12. The Short Broadcast message is manually initiated by the operator at the DTS.

### Broadcast Mode Messages

The Broadcast mode messages consist of a continuous series of short broadcast messages, separated by two frames of dead time, as shown in figure 2-13. The message format is the same as a picket reply message. In the Broadcast mode, only one unit will transmit.

### Net Test Mode

The Net Test message consists of the five-frame preamble, the phase reference frame, and the Net Test words generated by the DTS. When all the Net Test words in the library have been transmitted, the sequence starts over until the operator stops the Net Test.

## LINK-11 DATA TERMINAL SET (DTS)

As you have seen, the data terminal set is the heart of the Link-11 system. The DTS performs the modulation, demodulation, and control functions required for proper Link-11 operation. It accepts data from the CDS computer in the form of 24-bit data words, adds six bits of error detection and correction (EDAC) data, and converts all 30 bits into an audio tone package that is sent to the transmitter portion of

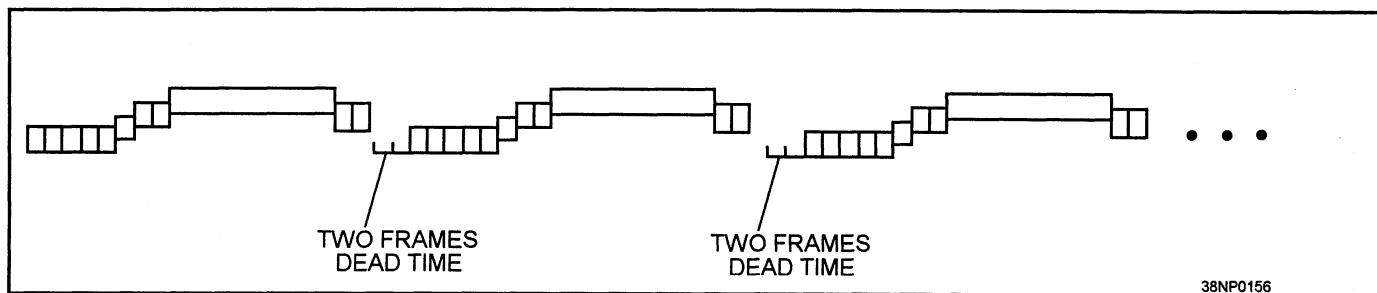


Figure 2-13.—Broadcast mode message format.

the radio set. The key-line signals necessary to control the transmit and receive states of the radio set are also generated by the DTS. Data received from the upper sideband (USB) and lower sideband (LSB) portions of the radio set receiver, in the form of audio tones, is converted into parallel binary data and sent to the CDS computer.

Currently several design generations of Link-11 data terminal sets are used in the fleet. These include the AN/USQ-59 and 59A, the AN/USQ-63, and the AN/USQ-74. Originally introduced in the early 1960s, each successive generation of the Link-11 data terminal set reflects additional knowledge gained from fleet use and advances in technology. Although the technology used in the different models of the Link-11 DTS may be vastly different, all of them perform the same function.

Normally, the DTS operates in the **half-duplex**

mode, meaning it can either receive or transmit data, but it cannot do both at the same time. An exception is during system test when the DTS operates in **full-duplex** mode and can simultaneously send and receive data.

### DATA TERMINAL SET FUNCTIONS

The DTS also performs the following functions:

- Error detection and correction
- Audio signal generation
- Link-11 protocol and interface control

### Error Detection and Correction (EDAC)

The DTS receives data from the CDS computer in the form of 24-bit binary data words. The 24-data bits

Table 2-1.—DTS Parity Bit Status Codes

MODE	ERROR STATUS	BIT POSITION	
		25	24
<b>Detect and Label</b>	No errors detected	0	0
	Error(s) detected - no correction attempted	1	0
<b>Detect and Correct</b>	No errors detected	0	0
	Parity errors detected	0	1
	Odd error(s) detected - correction attempted	1	1
	Even errors detected - no correction attempted	1	0

are expanded to 30 bits by adding six bits for error detection and correction (EDAC). These six bits are also called **hamming** bits. The value of these bits is based on parity checks of specific combinations of the 24-bit data word.

During the receive cycle, the six EDAC, or hamming bits, are examined for errors. There is enough redundancy in the EDAC to allow for correction of a single bit error. The operator can control the selection of the error correction mode. If the data word is not a control word, the word is examined to determine if it is error-free, contains a correctable error, or contains uncorrectable errors. If the DTS is in the error detection and label mode, a detected error is identified and labeled before the data word is sent to the CDS computer. In the error detection and correct mode, the DTS attempts to correct an error before sending the data word to the CDS computer. In both modes, the six EDAC bits are deleted and replaced with two parity error status bits. These status bits are defined in table 2-1.

### Audio Tone Generation and Characteristics

The DTS converts the 24-bit data word, along with the six EDAC bits, into a composite audio signal consisting of 16 tones. This composite 16-tone signal is the **data frame**. The tones range in frequency from 605 Hz to 2,915 Hz and are the odd harmonics of 55 Hz. The specific frequencies of the tones are shown in table 2-2. The 605-Hz tone is used for Doppler correction, and the 2,915-Hz tone is used for data and synchronization. Each of the data subcarrier tones (tones 2 through 16 in table 2-2) represents two binary bits of differential quadrature phase-shift modulated data.

The Doppler tone (605 Hz) is not phase modulated. It is used to correct for Doppler shifts in the received tones caused by the relative motion between the transmitter and the receiver. It is also used to correct for the Doppler shift that may occur because of differences between the transmitter and receiver frequency standards.

The 2,915-Hz tone has two separate uses. During the transmission of the preamble and Net Sync, the

2,915-Hz tone is used to identify frame timing. This tone is phase shifted 180 degrees at the end of each frame. When detected by the receiving DTS, the phase shift indicates the start of a new frame. When the DTS is in corrected timing, this information is used to set the timing for the data frames that follow. When stored timing is used, the frame timing that was set during Net Sync is used.

The Doppler and sync tones vary from each other and the other data-carrying tones in amplitude. The Doppler tone is 6 dB greater than the other tones. During the Net Sync and preamble frames, the Doppler tone is transmitted at 12 dB and the sync tone is transmitted at 6 dB. The Doppler tone is transmitted at 6 dB during the transmission of data frames and the sync tone is used as a data tone. Data tones are transmitted at 0 dB.

The audio tones are divided into data frames to identify the separate parallel groupings of 30 bits. It is the phase angle shift of each of the 15 data tones that conveys the digital information contained in the tone. During each frame, each data tone frequency has a particular phase. At each frame boundary, the phase of each data tone is shifted with respect to the previous frame. The amount of this phase change, or **phase difference**, determines the value of a two-bit number. Two data bits yield the following four possible combinations: 00, 01, 10, and 11. Each combination is associated with a phase difference of one of four values: 45 degrees, 135 degrees, 225 degrees, or 315 degrees from the previous position.

Each of these angles marks the center of a quadrant, as shown in figure 2-14. Each 90-degree quadrant is assigned a two-bit binary value. Any phase difference falling within that quadrant represents that binary value. This system of data encoding can tolerate an error in the prescribed phase shift of up to  $\pm 44$  degrees before a single bit error will occur. An error in phase shift that is greater than 45 degrees, but less than 135 degrees, will cause the phase angle to fall into an adjacent quadrant. Notice that the values are assigned to each quadrant in such a way that if a phase shift error occurs, only one bit error will be introduced as long as the quadrant into which it falls is adjacent to the target quadrant.

Table 2-2.—Tone Library

Tone Number	Frequency (Hz)	Description	Bit Location
1	605	Doppler	*
2	935	Data	0 and 1
3	1,045	Data	2 and 3
4	1,155	Data	4 and 5
5	1,265	Data	6 and 7
6	1,375	Data	8 and 9
7	1,485	Data	10 and 11
8	1,595	Data	12 and 13
9	1,705	Data	14 and 15
10	1,815	Data	16 and 17
11	1,925	Data	18 and 19
12	2,035	Data	20 and 21
13	2,145	Data	22 and 23
14	2,255	Data	24 and 25
15	2,365	Data	26 and 27
16	2,915	Data/Sync*	29 and 30

\* There is no bit location associated with the 605-Hz Doppler tone or the 2,915 Hz tone when used as the Sync tone

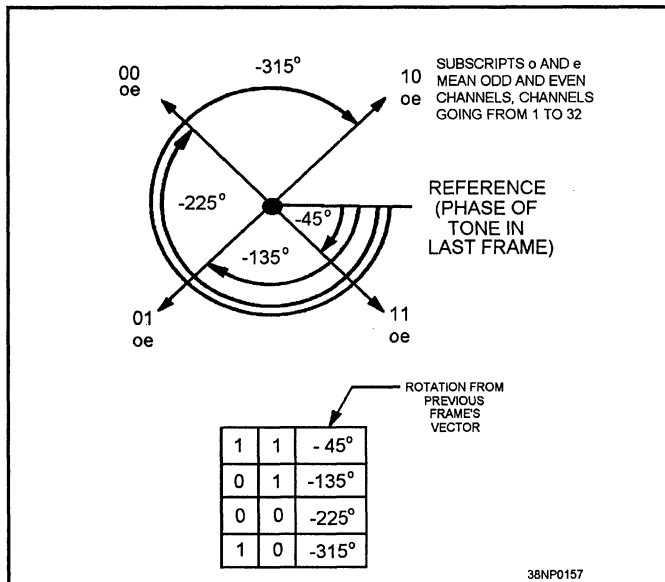


Figure 2-14.—Link-11 data phase shift encoding.

## Link Protocol and Interface Control

In addition to encoding data from the CDS computer, the DTS generates and recognizes protocol data that controls the type and number of link transmissions. These protocol words include codes indicating the start of transmission, the end of transmission, and the address of the next unit to transmit.

The interface with the CDS computer is under the control of the DTS. The DTS signals the CDS computer when it has input data or when it wants output data through the use of external interrupts. These interrupts include the prepare-to-transmit, prepare-to-receive, and end-of-receive interrupts.

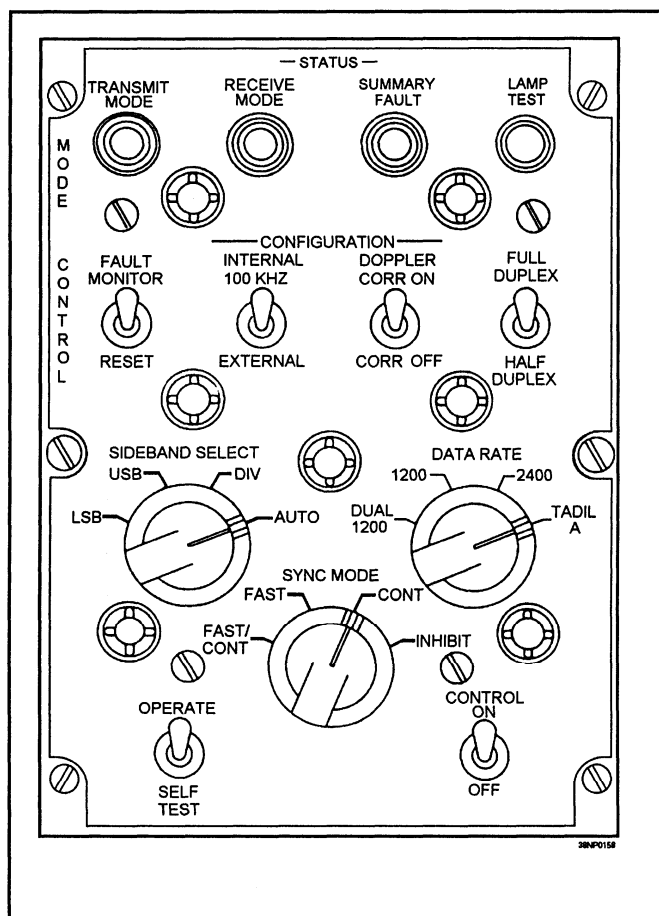


Figure 2-15.—The AN/USQ-59 Mode Control panel.

## DTS CONTROLS AND INDICATORS

Many parameters that affect the operation of the DTS are under the operator's control, whether the station is operating as a picket or as the net control station. Both the operator and the technician must be familiar with the various controls and indicators associated with the DTS. The AN/USQ-59 uses several control panels that are usually mounted next to the operator's display console. These panels enable the operator and the technician to control and monitor the net operation.

The control panels include a **Mode Control** panel, a **TADIL A Control** panel, and an **Address Selection Indicator** panel. Although the AN/USQ-59 control panels are used here to show the controls and indicators of a Link-11 DTS, other data terminal sets have similar controls.

### DTS Mode Control Panel

The DTS mode control panel controls and indicators are shown in figure 2-15. The following is a summary of how the controls affect the operation of the link and what the indicators mean.

**TRANSMIT MODE INDICATOR**— Lights when the DTS is in the transmit mode.

**RECEIVE MODE INDICATOR**— Lights when the DTS is in the receive mode.

**SUMMARY FAULT INDICATOR**— Lights when a fault in the DTS is detected while the DTS is in the OPERATE mode. There are 27 performance monitor fault-sensing circuits in the data converter (modem) of the DTS. During the OPERATE mode, 14 of these sensors can cause a summary fault. The fault-sensing circuits monitor areas such as various power supplies, signal quality, preamble presence, timing, and audio signal quality. When the DTS is in SELF TEST, the summary fault lamp is lighted when a fault is isolated to a function defined by switch positions on the fault isolation control and built-in tests routines.

**LAMP TEST BUTTON**— Causes all indicators on the mode control panel, the TADIL A control panel, and the address control unit to light.

**FAULT MONITOR/RESET SWITCH**— In the MONITOR position, this switch allows the fault-sensing function of the DTS to operate normally and provide a fault summary signal to the DTS control. When the switch is placed in the RESET position, the fault-sensing circuits of the DTS are reset. The SUMMARY FAULT lamp is turned off when the fault-sensing circuits are reset.

**INTERNAL 100 KHZ/EXTERNAL SWITCH**— Allows for the selection of the internal or external 100-kHz frequency standard.

**DOPPLER CORR ON/CORR OFF SWITCH**— Enables the DTS Doppler correction when placed in the CORR ON position.

**FULL-DUPLEX/HALF-DUPLEX SWITCH**— In the FULL-DUPLEX position, this switch enables full-duplex operation of the data converter and the computer I/O adapter. It also enables loop back processing of the transmit sidetone data for input to the computer. In the HALF-DUPLEX position, the DTS operates in the half-duplex mode and the transmit sidetone is disabled from being processed and input to the computer. Link-11 uses the half-duplex mode.

**SIDEBAND SELECT SWITCH**— When the SIDEBAND SELECT switch is placed in the LSB or USB position, the DTS processes only the lower sideband or upper sideband of the received signal. When the switch is in the DIV position, the DTS combines both the upper sideband and the lower sideband signals to create frequency diversity data for input to the computer. When the switch is in the AUTO position, the DTS selects the signal with the best receive quality for processing. The AUTO position is the normal position of this switch.

**DATA RATE SWITCH**— Selects the data rate that the data converter uses. When the switch is in the DUAL 1200 position, the data converter can transmit and receive two unrelated streams of data at 1200 bps. When the switch is in either the 1200 or 2400 position, the data converter transmits and receives a single data stream at 1200 or 2400 bps, respectively. When the switch is in the TADIL A position, the data rate is controlled by the DATA RATE switch on the TADIL A control panel. The TADIL A position is the normal position for Link-11.

**SYNC MODE SWITCH**— The SYNC MODE switch selects the mode of synchronization used by the DTS receive circuitry and is used in conjunction with the TIMING STORED/CORRECTED switch on the TADIL A control panel. The normal operating position for the SYNC MODE switch is in the FAST/CONT position.

When the switch is in the FAST/CONT position, both the fast and continuous synchronization circuits of the DTS are selected. Synchronization is initially obtained during the five-frame preamble and maintained continuously during the data portion of the

transmission. The TIMING switch on the TADIL A control panel must be in the CORRECTED position.

When the FAST position is selected, synchronization is only during the five-frame preamble. If the CONT position of this switch is selected, only the continuous synchronization circuits are selected. Synchronization is obtained only during the data portion of the transmission. The TIMING switch on the TADIL A control panel must be in the CORRECTED position for both of these modes.

The INHIBIT position of this switch disables both the fast and continuous synchronization circuits of the DTS. The DTS will maintain the time base that was stored when the switch was turned to INHIBIT. For synchronization to be held, the unit with its sync mode inhibited must maintain its original geographic relationship to all other units in the net. This position is used when the received signal contains interference that could cause loss of synchronization.

**OPERATE/SELF TEST SWITCH**— This switch must be in OPERATE for normal on-line operations. When the switch is placed in the SELF TEST mode, the DTS is placed in an off-line mode and the fault isolation circuitry is enabled.

**CONTROL ON/OFF SWITCH**— When the CONTROL switch is placed to the ON position, +28Vdc is applied to the fault isolation control panel, the mode control panel, the TADIL A control panel, and the address control panel.

### **TADIL A Control Panel**

The TADIL A control panel provides the control switches and indicators required to control and monitor Link-11 operations. Figure 2-16 shows the AN/USQ-59 TADIL A control panel.

**XMT DATA ERROR INDICATOR**— This indicator is lighted when the DTS detects an error while transmitting data in the TADIL A, or Link-11, mode.

**RCV DATA ERROR INDICATOR**— This indicator is lighted when the DTS detects an error in received data being sent to the CDS computer.

**CODE ERROR INDICATOR**— The CODE ERROR indicator is lighted when the DTS detects an error in the received or sidetone (transmit) control codes during TADIL A operations.

**NET BUSY INDICATOR**— The NET BUSY indicator is lighted when the DTS detects that the communications net is busy. It is activated when a signal called **signal presence** is generated by the DTS.

**SYNC COMPT INDICATOR**— The SYNC COMPT indicator is lighted continuously, or flashes, when the DTS has achieved synchronization with the NCS data terminal.

**TIMING STORED/CORRECTED SWITCH**— The TIMING STORED/CORRECTED switch determines how the DTS is synchronized. When the switch is in the CORRECTED position, the fast synchronization and/or the continuous synchronization circuitry in the DTS is used. The position of the sync mode switch on the mode control panel determines whether the fast, continuous, or both circuits are used to maintain synchronization. When the switch is in the STORED position, the DTS uses the time base stored during Net Sync. During normal operations, this switch should be in the CORRECTED position.

**OPERATE/RADIO SILENCE SWITCH**— The OPERATE/RADIO SILENCE switch is a two-position toggle switch that allows the DTS to inhibit radio transmissions. When the switch is in the OPERATE position, the DTS operates normally. When the switch is switched to the RADIO SILENCE position, the radio keyline and transmit audio circuits are immediately disabled.

**NET CONTROL/PICKET SWITCH**— The NET CONTROL/PICKET switch configures the DTS to operate as the net control station or a picket station in Roll Call mode.

**ERROR CORRECT/LABEL SWITCH**— The ERROR CORRECT/LABEL switch determines how the DTS processes detected errors. When the switch is in the CORRECTED position, the DTS attempts to correct detected errors. If a single bit error is detected, the location of the erroneous bit is detected and corrected. If an even number of bit errors occurs, the correction circuitry is inhibited. If an odd number of bit errors occurs, the correction circuitry attempts to correct the data; however, if an odd number of multiple bit errors occurs, an erroneous correction is made. When the switch is in the LABEL position, the DTS does not attempt to correct detected errors. Instead, the data word sent to the computer is labeled to indicate that errors were detected in the data word.

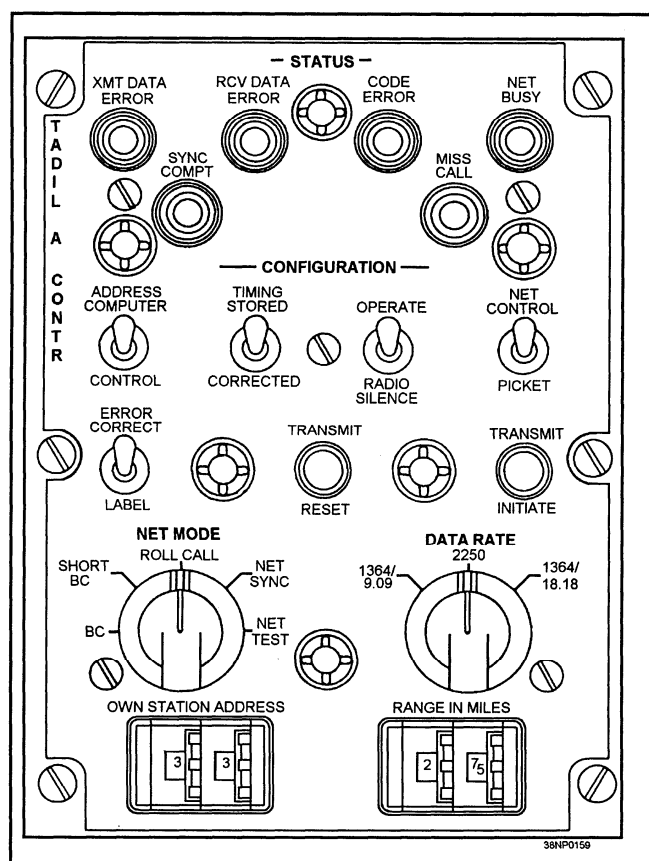


Figure 2-16.—The AN/USQ-59 TADIL A control panel.

**TRANSMIT RESET SWITCH**— The TRANSMIT RESET switch is a momentary contact pushbutton switch. When depressed, this switch causes any transmission in progress to be terminated. The DTS stops the transmission by inhibiting the generation of the output data request, causing a stop

code to be transmitted. The DTS also resets the address control address sequence logic.

**NET BUSY INDICATOR—** The NET BUSY indicator is lighted when the DTS detects that the communications net is busy.

**TRANSMIT INITIATE SWITCH—** The TRANSMIT INITIATE switch is a momentary contact pushbutton switch that causes the DTS to initiate data transmission when the DATA RATE switch is in the TADIL A position. The TRANSMIT INITIATE switch must be depressed to initiate all DTS transmissions except when the DTS is configured as a picket and is in the Roll Call mode. When the net is in the Roll Call mode, only the net control station is required to initiate transmission by depressing the TRANSMIT INITIATE switch.

**MISS CALL INDICATOR—** The MISS CALL indicator is lighted when the net control station has detected no response from a picket station after two successive interrogations. Once lit, it will remain lit until a picket responds or the TRANSMIT RESET switch is depressed.

**ADDRESS COMPUTER/CONTROL SWITCH—** The ADDRESS COMPUTER/CONTROL switch determines the source of the address used by the DTS. When the switch is in the CONTROL position, addresses are obtained from the address control unit. When the switch is in the COMPUTER position, addresses are obtained from the CDS computer, provided the computer is configured for external function operations. The normal position for this switch is depends on the configuration of the system on your ship.

**NET MODE SWITCH—** The NET MODE switch determines the mode of operation of the DTS. The modes are BC or broadcast, SHORT BC, ROLL CALL, NET SYNC, and NET TEST.

**DATA RATE SWITCH.—** The DATA RATE switch determines the speed and frame timing operation of the DTS. When the switch is in the 1364/9.09 position, the DTS transmits and receives data at 1364 bps. The data frame phase identification

interval is approximately 9.09 milliseconds. When the switch is in the 2250 position, the DTS transmits and receives data at a rate of 2250 bps and a frame interval of 9.09 milliseconds. When the switch is in the 1364/18.18 position, the data rate is 1364 bps, but the frame phase shift interval is increased to 18.18 milliseconds.

**OWN STATION ADDRESS SWITCH—** The OWN STATION ADDRESS switch consists of two thumb wheel switches in which an address is entered to identify the address the DTS will respond to as its own. In the Roll Call mode and with the DTS configured as a picket station, the DTS will transmit its tactical data when the interrogation message address matches the address entered into the OWN STATION ADDRESS switches.

**RANGE IN MILES SWITCH—** The RANGE IN MILES switch also consists of two thumb wheel switches. These switches are used to select the approximate distance between the net control station and the picket station. The range entered into these switches causes the DTS to alter the frame timing to compensate for the signal propagation delay between the picket station and the NCS. The range in miles setting for the NCS is always zero miles.

### **Address Control Indicator**

The address control indicator is used to set the address of the picket stations to be interrogated when a unit is configured to operate as the NCS. The address control indicator is shown in figure 2-17. The address control indicator consists of 20 identical address selection modules, which are used to address up to 20 stations. More than one address control indicator may be installed in a system to provide the ability to interrogate more than 20 stations.

Each address selector module has two thumb wheel switches in which one of 64 octal addresses may be entered (address 00 and 77 octal are invalid). Also, each address selector module has a power on/off switch, a power on indicator lamp, and a call indicator, as shown in figure 2-18.



When a unit is configured as the NCS, the operator enters all the assigned addresses of the net participating units into the address selector modules, and turns on each module with a valid address. Once the Roll Call mode is initiated, the DTS will check each module sequentially. If the power of the module is on and a valid address is entered, the address is sent to the DTS for use in an interrogation message. If the power switch is in the OFF position, that module is skipped, even if it contains a valid address. When enabled by the DTS, the address selector module sends the address entered in the thumb wheels to the DTS and the call indicator light. The call indicator will remain lit until the DTS sequences to the next address module.

## CDS INPUT/OUTPUT CONTROL

The data terminal set controls the exchange of data with the CDS computer. As describe earlier, input/output communications protocol is accomplished through the use of external interrupts. The prepare-to-transmit data interrupt, the prepare-to-receive data interrupt, and the end-of-receive data interrupts control the DTS to the computer interface.

### CDS Computer Input (Receive) Data Cycle

The input data cycle is initiated by the DTS. When the DTS recognizes the second frame of the start code, it sets the prepare-to-receive data interrupt on the input data lines and sets the external interrupt line. The computer acknowledges the receipt of the interrupt by sending an input data acknowledge (IDA) to the DTS.

Upon receipt of the first message frame, the DTS demodulates the 24-bit word and places it on the input data lines, along with the two error detection and correction bits. Once the data is placed on the input data lines, the DTS sets the input data request (IDR) line. The computer will sample the data and send an IDA. This process repeats for all frames of the message. The first frame of the stop code is also treated as a message frame and sent to the CDS computer. When the DTS recognizes the second frame of the stop code, it will place the end-of-receive interrupt on the input data lines and set the interrupt

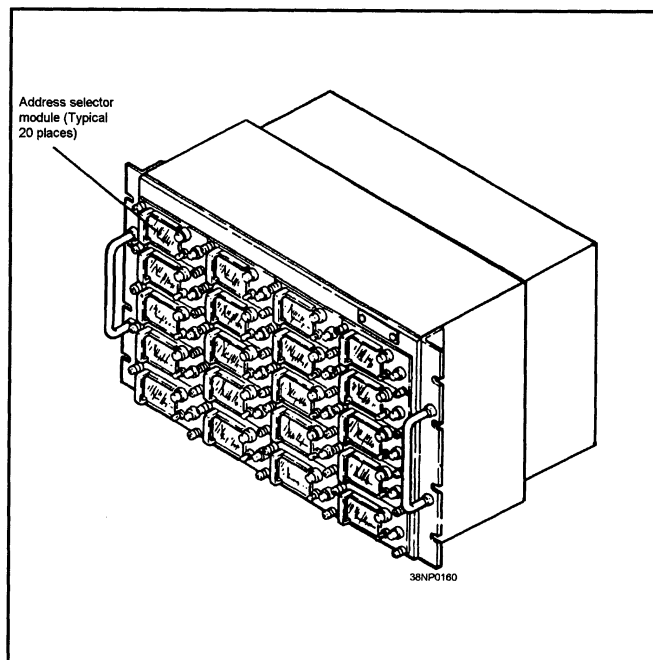


Figure 2-17.—The Address Control Indicator C9062/U.

line. The interrupt is then processed by the CDS computer and the input buffer is closed.

If the received stop code is a picket stop code, the DTS simply resets itself. If the stop code is a control station stop code, the DTS will compare the next two frames received with its own station address code.

### CDS Computer Output (Transmit) Data Cycle

The output data cycle is initiated when the DTS detects its own station address, either in an

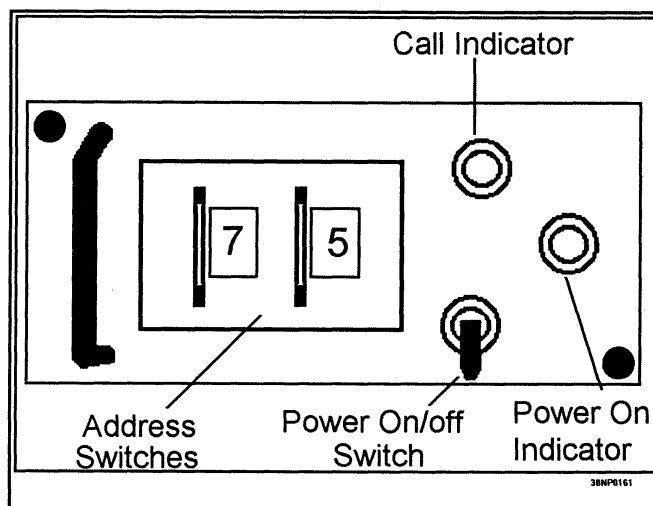


Figure 2-18.—An address selector module.

interrogation message or at the end of an NCS report and interrogation message. When the DTS recognizes its own station address, it starts to transmit the preamble. During the first frame of the preamble, the DTS sets the prepare-to-transmit interrupt on the input data lines. The computer samples the interrupt and sends an IDA to acknowledge receipt of the interrupt.

The DTS finishes sending the preamble and phase reference frames. During the second frame of the start code, the DTS sets the output data request (ODR) active, requesting the first word of the tactical data. The CDS 'computer responds by placing 24 bits of data on the lines and then setting the output data acknowledge (ODA). The DTS samples the data and clears the ODR. The first frame of data is processed for transmission and the ODR line is then set to request the next data word.

This procedure is repeated until all the data words have been transmitted. Once the CDS computer has completed sending all the data words, it will not acknowledge the ODR from the DTS. If the CDS computer has not acknowledged an ODR from the DTS in a preset amount of time, the DTS will clear the ODR line and generate a stop code. Upon transmission of the two-frame stop code, the DTS will return to the receive mode.

### Net Control Station (NCS) I/O Operations

The station acting as NCS follows the same protocols when communicating with the CDS computer. Some differences exist in the generation of the control codes. The net control station is responsible for interrogating each station. Upon receipt of a picket stop code, the DTS checks the next station address and sends an interrogation message. After the interrogation message is transmitted, the DTS waits to receive a start code from the interrogated station. If a start code is not recognized after 15 frame intervals, the station will be reinterrogated. If a start code is not received after another 15 frame intervals, the address control unit will advance to the next active picket address and repeat the interrogation process.

The other major difference is when the net control station has completed its own tactical data transmission, a control stop code, followed by the next station address, is transmitted. Again, if a start code is not received within 15 frame intervals, a second interrogation is sent. This second interrogation is a normal interrogation message consisting of the preamble, phase reference frame, and address code.

### Modulator/Demodulator

The modulator/demodulator function of the DTS provides the digital to analog and analog to digital conversion. During data transmission, the 24-bit binary data word is expanded to 30 bits by adding the six bits for error detection and correction. The 30 bits are then examined in pairs to determine the required phase angle shift for each of the 15 data-carrying tones in the audio package.

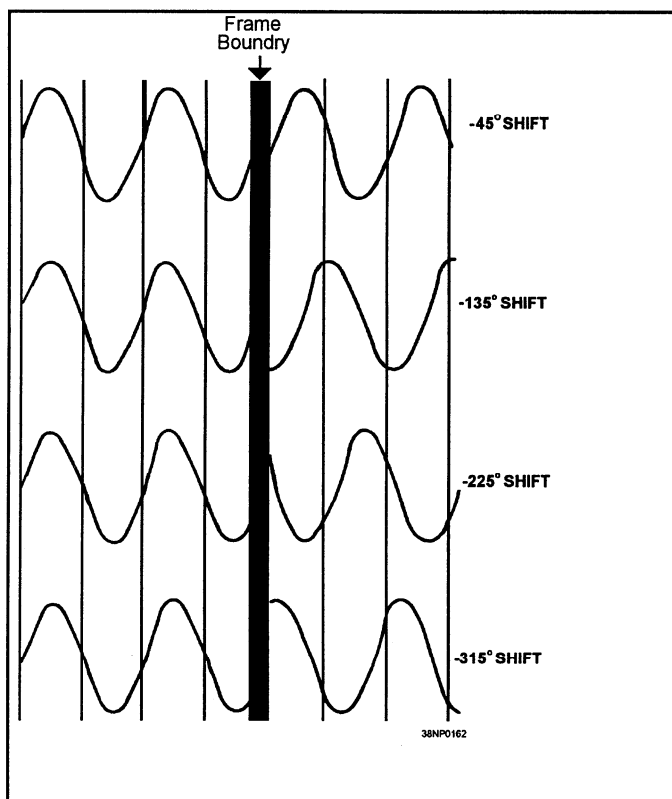


Figure 2-19.—Link-11 frame boundary phase shifts.

At the frame boundary, the phase of each data tone is shifted with respect to the previous frame.

Figure 2-19 shows the four possible phase shifts. A sixteenth tone, the 605-Hz Doppler correction tone, is added to the tone package. The Doppler tone is not phase modulated and is used to correct for Doppler shifts caused by the relative motion between the transmitting station and the receiving station. The 16 tones are combined into a composite audio signal and sent to the radio set. The radio set transmits the composite tone package on the carrier frequency in independent sideband form.

During receive operations, the tone package is received from the radio set. The 30 bits of data are extracted from the tone package by determining the phase shift of each data tone with respect to the previous frame. The 30 bits, which contain 24-data bits and six-EDAC bits, are examined for errors. The six-EDAC bits allow for the detection of errors and provide enough redundancy to allow for correcting a single bit error.

The operator can select whether or not the DTS attempts to correct detected errors, as explained earlier in this chapter. In the error detect (label) mode, a detected error is identified and labeled before it is sent to the CDS computer. In the error correction (correct) mode, the DTS attempts to correct a detected error, labels the error, and sends the data word to the CDS computer.

The DTS is capable of receiving and processing both the upper sideband and the lower sideband when using a HF radio, depending on the position of the sideband select switch. When you are using a UHF radio, only the upper sideband is received and processed.

If the sideband select switch is in the USB or the LSB position, only the designated sideband is processed. In the diversity (DIV) mode, the 30-bit word is generated by adding the relative phase angles of the USB and the LSB.

Because of propagation anomalies, noise, and interference, the AUTO mode can be used to select the sideband (USB, LSB or DIV) that yields the most correct data automatically. In the AUTO mode the DTS processes a word from each sideband and the

diversity combination. The decoded words are examined for errors in the following order or priority: DIV, USB, and LSB. A search of the three words is made to find a data word with no error. If one is found, it is selected for input to the CDS computer. If none is found, the RCV DATA ERR indicator is lit and the diversity combination data word is sent to the CDS computer.

## **Radio Set Interface**

The DTS generates the following outputs to the radio set: upper sideband composite audio, lower sideband composite audio, and key line. It receives upper sideband composite audio and/or lower sideband composite audio. UHF radio sets use only the upper sideband signal and the key-line signal.

The key-line signal controls the transmit and receive state of the radio set. The key line is set to transmit Link-11 data. When the key-line is cleared, the radio set returns to the receive mode.

## **SUMMARY—THE LINK-11 SYSTEM**

This chapter has introduced you to the Link-11, or TADIL A, system. The following information summarizes important points you should have learned.

**LINK-11 SYSTEM—** Link-11 is used to transmit REAL-TIME tactical information between CDS-equipped ships and similarly equipped ships, aircraft, and shore stations. The typical shipboard configuration of Link-11 hardware consists of the following:

- CDS computer
- Shipboard Gridlock System
- Cryptographic security device
- Data terminal set
- Communications switchboard
- HF or UHF radio set

Antenna coupler and antenna

**LINK-11 NET OPERATING MODES—** The six modes of Link-11 operation are as follows:

Net Synchronization

Net Test

Roll Call

Broadcast

Short Broadcast

Radio Silence

The Net Synchronization mode establishes the initial time base between the NCS and all participating units. The Net Test mode tests the connectivity of all units in the net and the operation of the DTS. The Roll Call mode is the normal mode of Link-11 operations. The Broadcast mode allows a single unit to transmit tactical data to all other units repeatedly. The Short Broadcast mode allows a unit to broadcast its tactical data once every time the operator depresses the transmit start switch. Radio Silence allows a unit to receive Link-11 data, but that unit will not transmit data.

**BUILDING A LINK-11 MESSAGE—** A Link-11 message consists of the preamble, the phase reference frame, and the information segment. The preamble is five frames long and contains the 605-Hz Doppler tone and the 2,915-Hz sync tone. The phase reference frame is one frame and provides a starting reference for the information segment. The information segment of the Link-11 message contains control codes and tactical data. Control codes are the start codes, the stop codes, and the address codes.

**LINK-11 MESSAGE FORMATS—** The format of a Link-11 message is depends on the mode of operation. The Roll Call mode consists of the following three different messages: the call-up (interrogation) message, the NCS report and call-up message, and the picket reply message. The call-up message consists of the preamble, the phase reference

frame, and the address code of the unit being interrogated. The NCS report is made up of the preamble, the phase reference frame, the start code, the tactical information, the control stop code, and the address of the next unit. The picket reply message is comprised of the preamble, the phase reference frame, the start code, the tactical data, and the picket stop code.

The Broadcast and Short Broadcast messages are the same format as a picket reply message. In the Broadcast mode, one unit repeatedly broadcasts its tactical data and all other units in the net monitor this data. In the Short Broadcast mode, the operator must initiate each transmission of data.

In the Net Synchronization mode, the message is a continuously broadcast preamble. The Net Test mode message consists of the preamble, the phase reference frame, and a preset series of data words that are repeated until the test is stopped by the operator.

**LINK-11 DATA TERMINAL SET (DTS)—** The Link-11 data terminal set is the heart of the Link-11 system. The data terminal set performs the modulation, demodulation, and control functions required for Link-11 operations.

**DTS ERROR DETECTION AND CORRECTION (EDAC)—** The DTS is capable of detecting and correcting single bit errors in received data. It accomplishes this correction by decoding the six hamming bits that are added to the 24-bit data word by the transmitting DTS. When a correction is made, if there are multiple errors or the DTS is in the error detect and label mode, the error is designated by two parity bits added to the 24-bit data word before the data is sent to the CDS computer.

**DTS AUDIO TONE GENERATION AND CHARACTERISTICS—** The DTS generates a 16-tone composite audio signal. It converts (modulates) the 24 data bits into 12 audio tones. Each tone contains two data bits. Added to these 12 tones are the three tones containing the six EDAC hamming bits. A sixteenth tone is used for Doppler correction. The audio tones are the odd harmonics of 55 Hz. The

data and hamming tones are quadrature phase shifted with respect to the previous frame.

**LINK-11 PROTOCOL AND INTERFACE CONTROL—** The DTS controls the proper protocols and interface with the CDS computer. The protocols are controlled by the generation of the control codes. Interface with the CDS computer is controlled by the DTS through the use of external interrupts.

**DTS CONTROLS AND INDICATORS—** The DTS control panels provide the operator the means for controlling the operation of the DTS. The physical design of the control panels of the various data terminal sets varies, but the panels all perform the same functions. Important controls include the sideband select switch, the data rate switch, the sync mode switch, and the net control/picket switch.

Indicators are provided to indicate several types of errors.

**ADDRESS CONTROL INDICATOR—** The address control indicator is used to set the addresses of the participating units in the net. The address control indicator is only used when the DTS is in the net control station mode.

**RADIO SET INTERFACE—** The radio set interface of the DTS provides for the transfer to and reception from the radio set of the composite audio tone package. The DTS receives the composite audio on the upper and lower sidebands when using HF frequencies and the upper sideband only when using UHF frequencies. The DTS provides a key-line signal to put the radio set in the transmit mode during the transmission cycle.

